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(54) Method of reducing the effect of narrowband jammers in radio communication between two stations.

(57) A method for reducing the effect of narrowband jammers in communication between two stations utilising frequency hopping. A new frequency at a hop is not selected merely with the aid of random number generation, but also with learnt knowledge of the radio communication surroundings affecting the selection. The frequencies ($f_1 \ldots f_n$) available for frequency hopping are stored with different status in a list (X). The status of the different frequencies is determined by quality measurement of the channel selected in a radio communication, and by examining the status of the selected frequency (f_x) in relation to the status of the remaining frequencies ($f_1 \ldots f_n$).

EP 0 182 762 A1

METHOD OF REDUCING THE EFFECT OF NARROWBAND JAMMERS IN RADIO COMMUNICATION BETWEEN TWO STATIONS.

TECHNICAL FIELD

The invention relates to a method according to the preamble to claim 1, where the participating, communicating radio stations utlilise bandspreading, i.e. spreading the frequency bands used by so-called frequency hopping with the aim of avoiding external interference sources, here referred to as jammers.

BACKGROUND ART

In an environment including narrowband jammers, substantial reduction of the effect of the jammer is enabled by utilising bandspreading. In principle the jammer may be of two kinds: a) self-evidently known jammers such as local TV stations, the frequency bands of which are known, and can therefore be avoided from the beginning of communication, and b) jammers operating at known or unknown frequency or frequency band during communication.

The jammers according to b) are those most difficult to avoid.

Radio communication using frequency hopping to provide bandspreading is already known in the art, e.g. as in EP-A1-0068690. In this known system each signal received is analysed as to its quality. If more than one radio connection (transceiver) has hopped to the same frequency, no new signal is sent on the frequency of the received signal, but is replaced by the frequency of a signal received earlier or later. Colliding frequencies are thus taken into consideration in this known system, but the frequency hop takes place solely through the selection of the frequency by random number generation.

DISLOSURE OF INVENTION

In a conventional frequency hopping system a new frequency f_n is generated by a random numer r_n being created and used as an argument in a function $H(r_n)$, i.e. $F_r = H(r_n)$. The selection of the frequency F_r in receiver and transmitter shall give the same values in the transmitter and receiver that are to

communicate.

In the adaptive frequency hopping system intended by the method in accordance with the present invention, new frequencies are not solely determined by random numbers. Learnt knowledge of the environment around the radio connection is to affect the selection. While operating the connection such knowledge is collected, and can be stored in the receiver, e.g. as a list X of the radio channels used. The list X will then be the knowledge gained, and its contents can continuously, or after interruption, be updated in time with the different frequency hops.

The object of the present invention is to provide a method of eliminating or reducing the effect of external interference sources in a radio connection, using frequency hops where the selection of frequencies is not solely dependent on random number generation, but also on knowledge of the jamming or interference environment which is continually collected during the operation of the radio communication system.

Examples of the knowledge that is collected are such as jamming frequencies and the level of the transmitter power in the system.

The distinguishing features of the method are disclosed in the accompanying claims.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be described in detail with reference to the accompanying drawings on which

Figure 1 is a time chart of the frequency hops,

Figure 2 is a diagram giving the status of used frequencies,

Figure 3 is a simplified block diagram of a radio connection between two stations, and

Figure 4 is a more detailed block diagram for explaining the inventive method.

BEST MODES FOR CARRYING OUT THE INVENTION

Figure 1 is a time chart for the frequency hops in a radio communication system.

The hop interval T_h determines the rate at which new frequencies are generated, e.g. by a random number generator. This means that frequencies are generated every T_h -th second. During the transmitting interval T_s communication is in progress at the frequency f_1. During the interval T_k, the so-called resetting interval, there is a hop to another frequency f_2. The method described here is applied during the interval T_s in the transmitter and receiver units at both communicating stations, while radio communication is silent during the interval T_k.

In the frequency hopping system applying the method, the new frequency f_2 is not solely determined by a generated random number. Learnt knowledge of the surroundings is also the affect the selection. The knowledge collected during operation of the stations is in a state matrix X, illustrated in Figure 2. The content in X can be updated dynamically during the transmitting interval T_s and the rate of change is $1/T_h$.

The state matrix X contains information on presently permitted and prohibited frequencies. The matrix has three rows and N columns, where N is the number of available frequencies in the frequency hopping system. In the first row there are the values for the mapping frequencies (see below). The second row shows the status of a frequency value giving a quality measure calculated with respect to parameters as signal strength and jamming. The third row contains a time index. In Figure 2 there is illustrated an example of a realisation of the X matrix.

Measurement of channel quality may be carried out actively by analysing errors in a received, known bit pattern, or passively by SNR (signal/noise ratio) measurements. Measurement is carried out in the receiver. The measurement result is denoted symbolically here as m. The measurement results must be available in both transmitter and receiver, and must consequently be transferred to the transmitter. This takes place in the so-called return information.

The following steps are carried out during an interval of T_h seconds:

1. Updating of the state matrix X with the results of previous channel quality measurements is carried out in both transmitter and receiver.

Symbolically: (X,m)---> X

The state matrix is possibly edited, meaning that previously prohibited frequencies are made permissible. The number of remaining permitted frequencies decides whether edition shall take place, and here the information in lines 2 and 3 in the matrix X is utilised.

2. A new frequency value is determined from the actual state matrix X. This is done in both transmitter and receiver.

When generating a new frequency value, a random number r_n is selected, which is an integer in the interval 1 to N. The value used is in the r_n - th permissible component in row 1 of X, i.e. $X(1, r_n)$ = the mapping frequency.

Symbolically: X---> new frequency value

Figure 3 illustrates the procedure in more detail in a block diagram. The transmitter TA in station A transmits a bit pattern of given duration together with possible synchronised information from the input i_1. The receiver MB in station B receives the bit pattern and decides channel quality with the aid of a bit-by-bit comparison. The result (in the form of a channel quality measurement) is multiplexed with the rest of the transmitted information from the input i_2 on the transmitter TB, and coded according to a suitable code insensible to jamming and known to station A. A block or a repetition code are suitable to use. The return information is then sent back to the receiver TA in station A, where it is de-multiplexed and used to update the status of the matrix X in the transmitter TA.

The described method is especially suited for duplex communication. In surroundings with slowly changing environment the method may also be used for the simplex mode.

In duplex mode, the return information is sent continuously in both directions. In simplex mode, return information is sent in one direction only for each transmission period. It takes a longer time to transfer the measurement results in simplex mode. However, if the environment changes slowly, so that the measurement results are not out of date when they are used, the method may also be used in simplex cases.

The block diagram of Figure 4 shows the parts most important for the frequency and power selection in the method described. The bit pattern which is multiplexed in the transmitter TA (Figure 3) is utilised partly for synchronising purposes, which is uninteresting in this connection partly for quality measurement on the receiver side MB.

The block diagram in Figure 4 corresponds either to station A or station B according to Figure 3. The transmitter side TA or TB includes a multiplexer MUX with three inputs s_1, s_2, s_3, and an output s_4, a modulator MOD for modulating the data signals from the output s_4, and a transmitter unit TX comprising a power amplifier and a mixer with input s_5 and output s_6, as well as further inputs connected to both outputs s_7, and s_8 from a microprocessor MD and to the output s_9 from a frequency synthesising unit FS1.

The receiver side RA (or RB) comprises a receiver unit RX having the input m_1, the output m_2 thereof being connected to a demodulator DEM corresponding to the demodulator MOD on the transmitter side. The output m_3 is connected to a demultiplexer DMUX, having the outputs m_4, m_5 and m_6, of which m_5 is connected via a measuring unit MT to the input of the microprocessor. The output m_8 of the microprocessor is connected to the frequency synthesizer unit FS2, the output m_9 of which is connected to the receiver unit FX.

A predetermined bit pattern is transmitted to the input s_3 from the microprocessor MD and coded return information from the encoder KD occurs at the input s_2, see below. Data from an external source that would normally be sent to station B is supplied to the input s_1 . The multiplexed data flow from the output s_4 is frequency shift modulated in the modulator MOD and supplied to the transmitter unit TX, where the modulated data signal is mixed with a given frequency f_x obtained from the frequency synthesising unit FS1. The frequency

f_x is one of the available hop frequencies f_1 - f_3 according to Figure 1, and the selection of a suitable frequency for the transmitter unit mixer is determined according to the described method. The output signal at the output s_6 is allowed to pass a circulator CR to the station antenna unit.

The microprocessor MD sends control signals for power and frequency from the outputs s_7 and s_8. Furthermore it sends a control signal from the output m_8 denoting what frequency f_y which, after synthesizing in the unit FS2, is to be supplied to the receiver unit RX to obtain demodulation of the incoming signal at the demodulator input m_2.

At its output m_5 the demultiplexer DMUX gives the bit pattern which has been transmitted from station B and which is now measured in the unit MT with respect to its quality. The result of the measurement is sent from the output m_7 to the microprocessor MD. In the latter a decision is made in accordance with a given algorithm as to the channel quality of the used frequency f_y (transmission: station B ---> station A). The channel quality is included in the return information from the microprocessor MD sent from the output S_{10} to the encoder KD. The return information, which occurs at the input s_2 and which is transmitted to station B after processing in the units MUX, MOD and TX thus indicates whether station A accepts the frequency f_y selected in station B. The bit pattern sent from output s_3 of the microprocessor MD towards the station B is used in the same way by the microprocessor in station B to decide whether the frequency f_x can provide reception such that it can be accepted by B. The decision is made in both station A and B as described above in connection with Figure 2. The block diagram of Figure 4 is also applicable for station B, with the difference that f_x is replaced by f_y and f_y by f_x. The frequencies f_x and f_y are different for duplex transmission, but what is decisive is that the transmitter in station A sends at the same frequency as the receiver in station B uses as reception frequency and vice versa. This is achieved by the microprocessor MD being implemented with two parts MD_x and MD_y. The processor part MD_x contains a state matrix X_x and a random number generator G_x for selecting different values for the frequency f_x during the frequency hop sequence. In a similar way the processor part MD_y contains a state matrix X_y and a random number generator G_y for selecting different values for the frequency f_y. The generators G_x and G_y each generate random number series

which are identically alike for stations A and B, i.e. the generator G_x in station A generates the same random number sequence as the generator G_y in station B, and the converse applying for the generator G_y. When transmission between the two stations starts the state matrices X_x and X_y are identical in both stations. Only the frequencies excluded from the beginning are prohibited in the starting situation.

During the communication (duplex) between stations A and B is quality measurement and transmission of return information taking place according to the above. A state set is then gradually built up in the matrices for the frequencies f_x and f_y determining the frequencies that may be used at the frequency hops. The status matrices in both stations A and B and for the frequencies f_x and f_y used will then be adjusted to the same status values.

The method in accordance with the invention can, as already indicated, also be extended to adjustment of the transmitted power, see items 3 and 4 above. The microprocessors in stations A and B thus contain a state variable Q giving the status of the power received from the transmitter units TX in the respective station. The measurement Q is updated for every frequency hop. In this situation Q is dependent on the previous value Q_1 and the quality measurement m, see item 3. It is then determined from the new status value, e.g. by reference comparison, whether the transmitter power shall be increased, reduced or remain unaltered (approved). The result of the comparison constitutes an order from the receiver to the transmitter in the communicating station, this order being conveyed via the return information. The output s_7 of the microprocessor MD sends control information regarding possible change in the transmitted power to the transmitter unit TX.

CLAIMS

1 Method for reducing the effect of narrowband jammers in radio communication between two stations (A and B) utilising frequency hopping, i.e. periodically changing the transmitter-receiver frequency from a given value to another with a given period (T_h), there being in said stations (A and B) a plurality of fixed frequency values (f_1, f_2, ... f_n), available for the frequency hops being stored together with pertaining mutually different status in a list (X), said frequencies being selected by random number generation, characterized in that a characteristic signal is sent from the transmitter in the first station (A) to the second station (B) to test the channel quality with respect to said jammers when communicating between the two stations (A and B), that the quality is measured in the receiver of the second station (B), that the result of said measurement is transmitted back to the receiver of the first station (A) in a form such that it is not affected by said jammers, and in that in the first station a decision is made on communication at the selected frequency (f_x, f_y) by examining, in response to said random number generation, the status of the selected frequency (f_x) in relation to the status of the remaining frequencies (f_1 - f_n) in said list (X).

2 Method as claimed in claim 1, characterized in that the quality of said channel is measured by comparing the transmitted signal in the receiver of the second station (B) with a previously determined second characteristic signal, and in that the result of the comparison is transmitted, in coded form so as not to be affected by said jammers, back to the receiver of the first station (A).

3 Method as claimed in claims 1 and 2, characterized in that the first characteristic signal is transmitted and transmitted back again together with other information transmitted between said stations (A and B).

4 Method as claimed in claim 1, characterized in that for a decision on selected frequency there is randomly generated a radio channel, the true value of which is determined from said list (X), which is updated in response to measured channel quality.

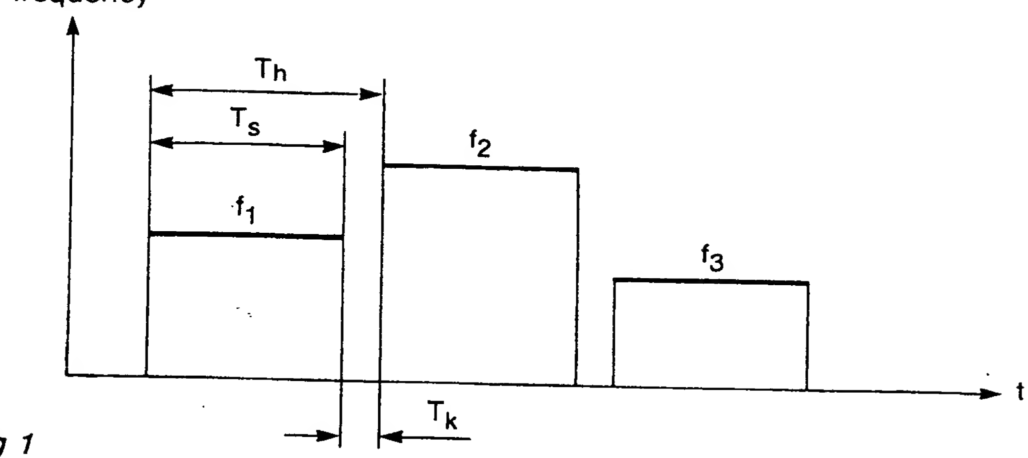

Fig 1

X-matrix

Mapping frequency	1	3	3	5	----	12	----	1
Status	0	1	0	2	----	−1	----	1
Time index	0	2	0	4	----	0	----	5

Fig 2

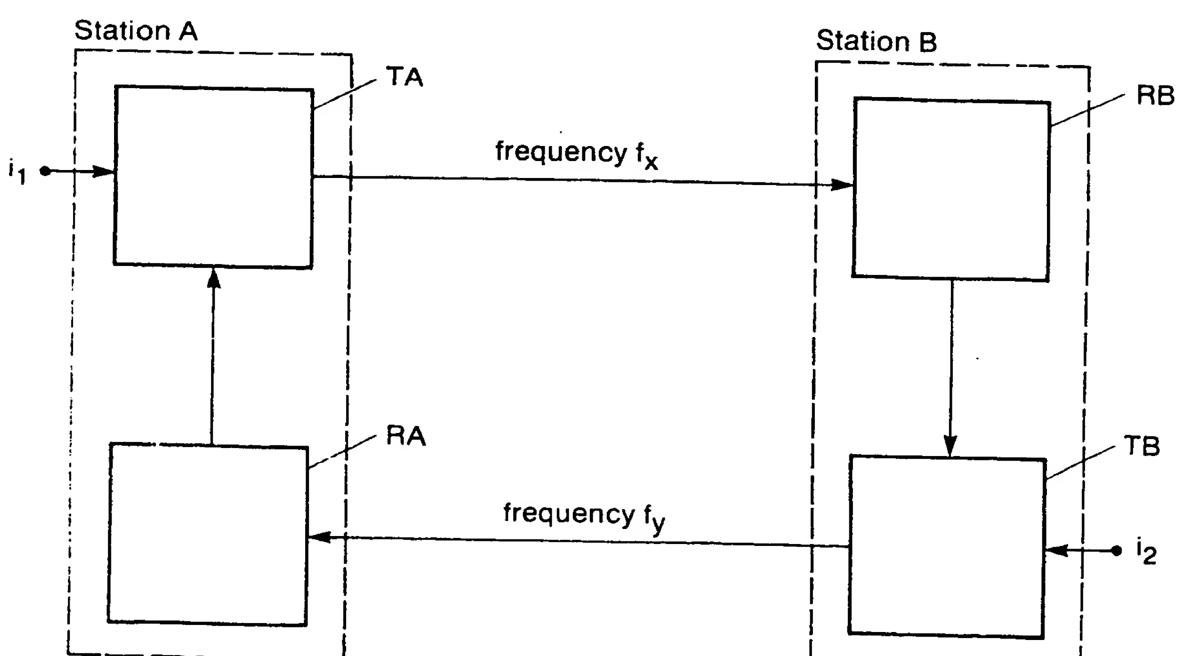

Fig 3

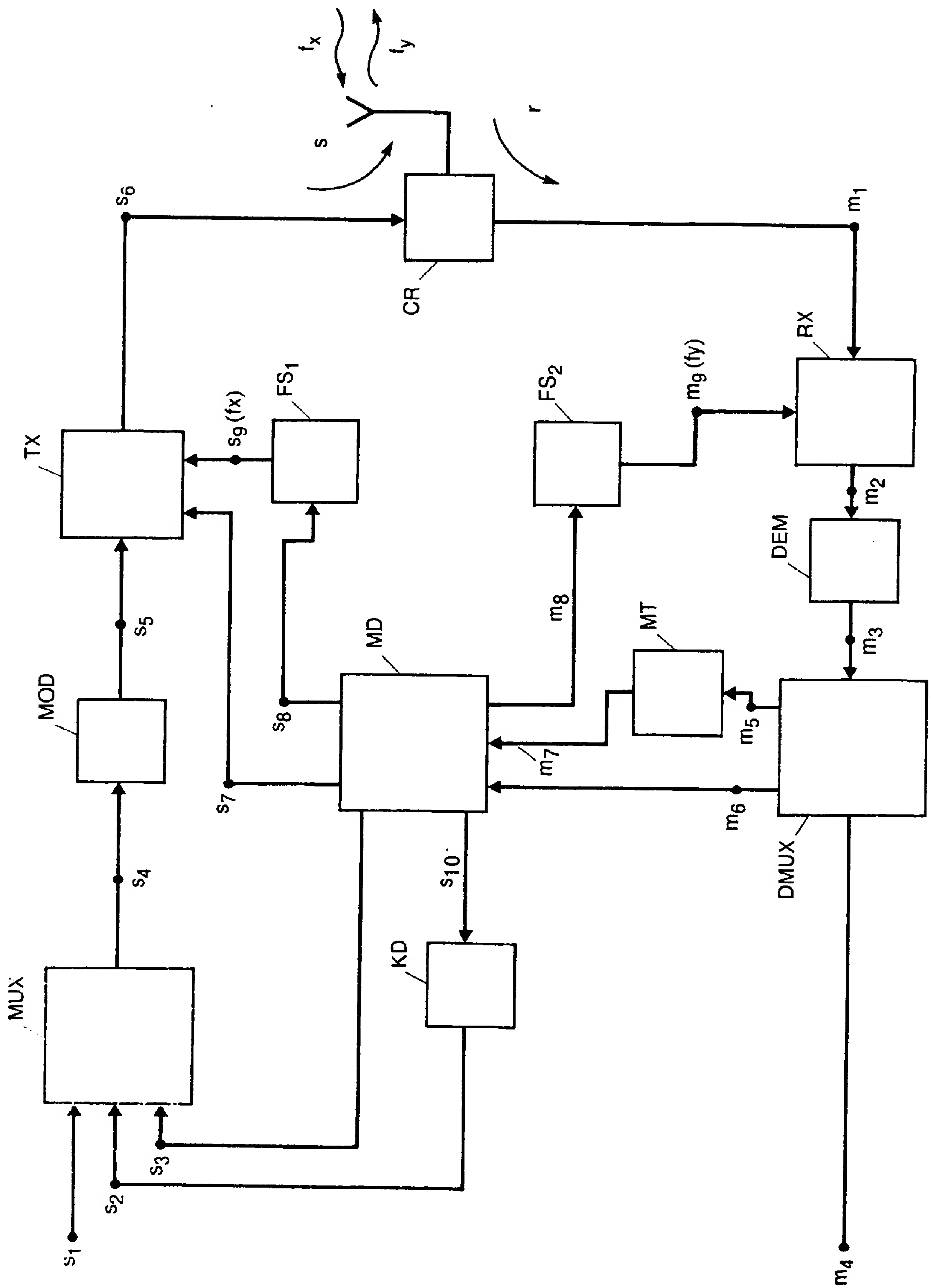
f_x
f_y
s
r
CR
s_6
m_1
RX
TX
FS_1
s_9 (fx)
FS_2
m_9 (fy)
m_2
DEM
MOD
s_5
MD
m_8
MT
m_3
s_8
m_5
m_7
s_7
m_6
DMUX
s_4
s_{10}
KD
MUX
s_3
s_2
s_1
m_4

Fig 4

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EUROPEAN SEARCH REPORT

0182762

Application number

EP 85850360.0

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-4 355 399 (TIMOR) *Whole document* ---		H 04 K 1/00
A	EP-A1-0 068 690 (THE MARCONI COMPANY LIMITED) *Whole document* ---		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			H 04 K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
STOCKHOLM	14-02-1986	FENGER-KROG S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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